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Issued September 30, 1912.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE—Bulletin 112.
HENRY S. GRAVES, Forester.

FOREST PRODUCTS LABORATORY SERIES.

FIRE-KILLED DOUGLAS FIR:

A STUDY OF ITS RATE OF DETERIORATION, USABILITY, AND STRENGTH.

BY

JOSEPH BURKE KNAPP,
Assistant District Forester, District 6.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., May 6, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "Fire-killed Douglas Fir, A Study of Its Rate of Deterioration, Usability, and Strength," by Joseph Burke Knapp, Assistant District Forester, District 6, and to recommend its publication as Bulletin 112 of the Forest Service.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

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FIRE-KILLED DOUGLAS FIR.

OBJECT AND METHOD OF STUDY.

Douglas fir (*Pseudotsuga taxifolia*) is unquestionably the most important timber tree of the northwestern United States. It grows in pure stands and in mixture with other species over much of the forested area from sea level to 3,000 or 4,000 feet elevation, reaching its best development in western Washington and Oregon. A great deal of Douglas fir has been the prey of forest fires, which have left immense quantities of dead standing timber.

The object of this study was to determine, through field observations, the rate at which fire-killed Douglas fir deteriorates and, through strength tests, the length of time that it remains merchantable; also to compare its mechanical properties and uses with those of wood from green trees.

A number of burns of different ages, presenting a wide range of conditions, were selected for observation, and an accurate history of each was secured. The ages varied from 1 to 43 years, but the greater number were the result of forest fires in 1902. Each burn was examined in detail, and since many were being logged there was opportunity, especially at the mills, for study of the interior condition of the trees and for noting the advance of deterioration. The strength tests, conducted in cooperation with the University of Washington, were made both on fire-killed and green timber. Further information was supplied from the experience of the logger, manufacturer, and user of fire-killed timber. The data obtained, although not complete in all respects, are indicative of average conditions throughout a large part of the range of the species.

ORIGINAL DESTRUCTION OF TIMBER.

Outside of dead trees, either fallen or standing, the actual destruction of timber by an ordinary fire of any of the three classes is usually not great, and, if the burned areas could be immediately logged, very little, if any, of the timber would be lost. Large trees are killed and remain standing, or are subsequently windthrown, while litter, ground cover, and young growth are usually consumed. In severe crown fires the tops are, as a rule, entirely consumed. In very intense fires, burning both in the tops and upon the ground, the trees are occasionally checked and develop wind shakes, which cause initial depreciation in the value of the timber.

DETERIORATION OF FIRE-KILLED TIMBER.

INSECTS.

The insects common in fire-killed Douglas fir, and which are of great importance in limiting the time the wood remains merchantable, work either as beetles or as wood-boring larvæ. The beetles, which work in the adult stage, are small and confine themselves to the bark or else make pinhole burrows in the sapwood. The active and most destructive larva forms, or borers, work extensively in the sap and then enter the heartwood, making numerous holes which detract greatly from the value of the wood.

In Douglas fir killed by a crown fire in midsummer insects work in the following way: Immediately after the fire the bark usually becomes infested with a small brown barkbeetle. The adult and its brood of larvæ so perforate and loosen the outer bark that ready access is afforded to the spores of wood-destroying fungi. Shortly after the fire several species of beetles deposit great numbers of eggs in cracks and crevices of the bark. When these eggs hatch, the larvæ bore into the inner bark and sapwood. These larvæ are known as round head (cerambyoid) and flat head (buprestid) borers. During the same summer a small pinhole beetle enters the sapwood through the bark and within one or two years extends its minute open mines to and sometimes slightly within the heartwood. During the two years following the fire the sapwood adjoining the mines of the pinhole beetles becomes considerably discolored, especially in the direction of the grain, and the various boring larvæ usually work in to a depth of about 3 inches.

At the end of five or six years the sapwood is in many cases completely penetrated by the roundhead borers and is beginning to break down in streaks through decay.

Eight or ten years after the fire the borers have extended their ravages into the heartwood, usually involving a ring from 3 to 12 inches thick, and the sapwood is entirely decayed. Now, the attacks of a very large roundheaded borer usually become apparent in the form of large mines in the heartwood, especially in the lower part of the tree. By this time, unless the timber is very large (over 3 feet in diameter) or the sap ring thin, the loss which would be occasioned by necessary excessive slabbing will, under existing market conditions, prevent the profitable manufacture of the timber.

A number of factors appear to affect the rate at which insects cause deterioration. The most important of these and the nature of their influence are:

(1) *Time of fire and degree of initial injury.*—Trees killed outright in the early summer or in midsummer present very favorable conditions for the establishment of large broods of insect larvæ. If, on the

other hand, the trees are killed late in the summer, or if they are not killed outright but so injured that death subsequently ensues, they are less seriously infested during the first year, and by the following summer apparently offer less favorable conditions for the destructive larvæ.

(2) *Effect of aspect and altitude.*—The aspect (or exposure) and altitude of the burned area appear to exert a considerable influence on the rate of insect workings, which is more rapid on the warm south and west aspects, and even on the south side of individual trees.

(3) *Effect of size of burn and proximity of former burns.*—Small, isolated burned areas in regions where fires have been infrequent suffer less from destructive insect attacks than do large burns in the vicinity of older ones.

(4) *Effect of sapwood.*—Douglas fir is usually classed by woodsmen as "yellow fir" and "red fir," the former being the old, slow-grown timber from close stands, the latter the younger timber of much more rapid and open growth. Large timber, because it is older and has relatively much less sapwood than younger and smaller trees, deteriorates much more slowly. Trees under 3 feet in diameter killed outright by a crown fire are usually so badly mined by borers as to be unmerchantable 8 or 10 years after being killed; larger trees with thin sapwood may remain merchantable for 15 to 20 years.

The upper part of the bole of a dead tree deteriorates more rapidly than the lower part because of the larger proportion of sapwood.

(5) *Down timber* is less subject to insect attacks than standing dead timber but decays more rapidly.

FUNGI.

Fungous diseases attendant upon the death of Douglas fir are very similar in their effects throughout that portion of its range covered by this study. They are usually distinct from previous heart and center rot, and it is very doubtful if decay in the thoroughly lignified portion of the bole is accelerated to any great extent by the death of the tree.

The spores of fungi destructive primarily to dead timber gain entrance to the wood through the lenticels, insect mines, and bark checks; and, since the conditions between the bark and wood are favorable to their development, give rise to fungi which attack the wood substance. In time the sapwood becomes stained and commences to break down, and white fungus threads or mycelia penetrate the various tissues. Usually no destructive results from fungi are apparent until after three or four years. From that time on decay is very rapid until the eighth or tenth year, when the sapwood is reduced to a disintegrated, worthless condition. In the heartwood, on the other hand, decay, as a consequence of the killing of the tree, is of very little importance within the first 10 or 15 years, in comparison with the deterioration caused by insects.

SEASONING.

Fire-killed Douglas fir does not suffer from season checks as much as do the species associated with it. In fact, while standing it shows no depreciation due to seasoning. Slight checking of the outer exposed wood of trees on old burns is sometimes visible, but this occurs in that portion of the trunk already made useless by the action of insects and fungi.

UTILIZATION OF FIRE-KILLED TIMBER.

LOGGING.

The logging of fire-killed timber sometimes involves bringing to the mill decayed material which must eventually be thrown away. Up to about four years after the killing, deterioration is confined to a ring of wood from 2 to 6 inches in thickness, the greater part of which would have been removed in slabbing anyhow, and therefore constitutes no loss. But when the deterioration has proceeded to a greater depth, some merchantable timber is either materially lowered in value or is rendered completely worthless. Logging burned timber also involves a considerable waste from breakage in felling, due to the seasoned condition of the wood and to the absence of limbs and foliage which check the descent and break the fall of the tree. This loss is largely governed by the logging area and length of time the timber has been killed, but often amounts to as much as 20 or 30 per cent. Sometimes there is danger to the fellers from decayed tops, which break off.

MILLING.

Fire-killed logs are manufactured into all forms of lumber usual to the species. As a rule, manufacturers have no strong prejudice against fire-killed timber. Where they purchase their logs in the open market on Puget Sound or the Columbia River, the price paid for fire-killed logs is generally the same as the market price for green logs, only the former are scaled inside the outer ring of worthless wood.

Many of the rafts consumed by large mills on Puget Sound and the Columbia River contain a considerable percentage of fire-killed logs. Logs which have decayed badly or have been seriously attacked by wood borers are rejected, but there are few such logs in the rafts.

In sawing fire-killed timber, it is sometimes necessary to exercise care in order to avoid the sapwood or heartwood discolored by incipient decay. The greater portion of the sapwood is removed in slabbing, but the slabs obtained from fire-killed logs are mostly unfit for conversion into lath.

The objection that abnormal checks and shakes, which it is claimed are found in fire-killed logs, cut down the mill scale of merchantable lumber is not substantiated by the observations made in this study.

The difficulty and expense of milling is increased by the gravel, which, in skidding on rocky ground, becomes embedded in the soft, decayed sapwood left exposed by the shattering and falling of the bark from the trunk when the trees are cut.

STRENGTH OF FIRE-KILLED TIMBER.

Because of the deteriorating influence to which fire-killed trees are subjected, many consumers of Douglas fir in structural forms are prejudiced against timbers manufactured from such trees, though they are unable to tell them from timbers made from green trees. It is claimed that fire-killed timber is brashy and does not have the strength and stiffness of that cut from growing trees.

In order to ascertain whether this is actually the case, tests were made on structural forms of fire-killed and green Douglas fir to determine their relative mechanical properties.

MATERIAL FOR TESTS.

The material for the tests was selected from an area near Yacolt, Clarke County, Wash., burned over by an intense forest fire seven years previously. In places the burned timber had deteriorated so badly that logging had been discontinued. The fire-killed trees selected showed some deterioration, the sap being decayed and insect attack slightly in evidence; but the test material was taken from the uninjured portions, and showed no evidence of decay or insect workings.

The logs from these trees were transported to a sawmill in Portland, Oreg., and manufactured into the following bill of material:[1]

Fire-killed:
  30 8″ x 16″ x 16′ bridge stringers.
  33 2″ x 12″ x 16′ floor joists.
  32 2″ x 10″ x 16′ floor joists.
  31 2″ x 8″ x 16′ floor joists.
Green:
  29 2″ x 12″ x 16′ floor joists.
  31 2″ x 10″ x 16′ floor joists.
  35 2″ x 8″ x 16′ floor joists.

---

[1] Appreciation is due to the Clarke County Timber Co. and to the Eastern & Western Lumber Co. for their cooperation in contributing, the former the timber, and the latter the service of manufacturing it.

This material was forwarded to the timber-testing laboratory of the Forest Service, operated in cooperation with the University of Washington, at Seattle.[1]

GRADING.

The fire-killed bridge stringers were graded according to the export grading rules of the Pacific Coast Lumber Manufacturers' Association which were effective in 1902.

The floor joists were classified by an arbitrary grouping system as follows: Each joist was theoretically divided into three volumes, designated as volume I, volume II, and volume III, as shown in figure 1. Those containing defects in volume I only were graded as group 1. Those containing defects in volume II and not in volume III, regardless of whether or not there were defects in volume I, were graded as group 2. Those having defects in volume III, regardless of the other two volumes, were graded as group 3. Joists containing no defects were designated as "clear."

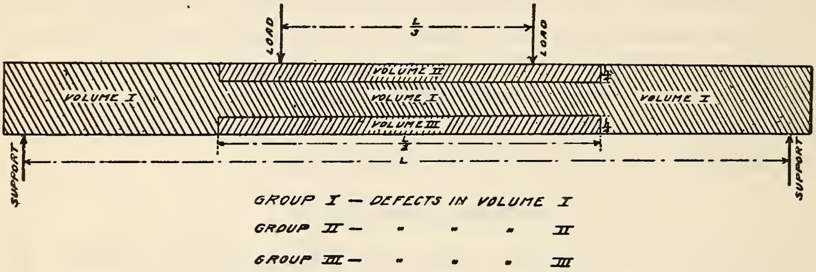

FIG. 1.—Division of joists with regard to position of defects.

MOISTURE DETERMINATIONS.

Figure 2 shows the method used in determining the distribution of moisture through the various timbers, and gives the average moisture content of the different sections as well as that of the full-sized disks. The test pieces represented were sawed from the interior both of the green and fire-killed logs.

Since these moisture determinations show that fire-killed timber has approximately the same moisture content as green timber, it is evident that the interior heartwood of fire-killed trees is as moist as the heartwood of green trees.

BRIDGE STRINGERS.

The fire-killed bridge stringers were tested on a span of 15 feet by applying the load at two points, each one-third of the length of the span from the nearest support. They were worked to destruction, and data for computing the various strength functions were recorded during the progress of the tests.

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[1] The tests were conducted under the immediate direction of Mr. O. M. P. Goss, of the Forest Service, who also made the analysis of the results.

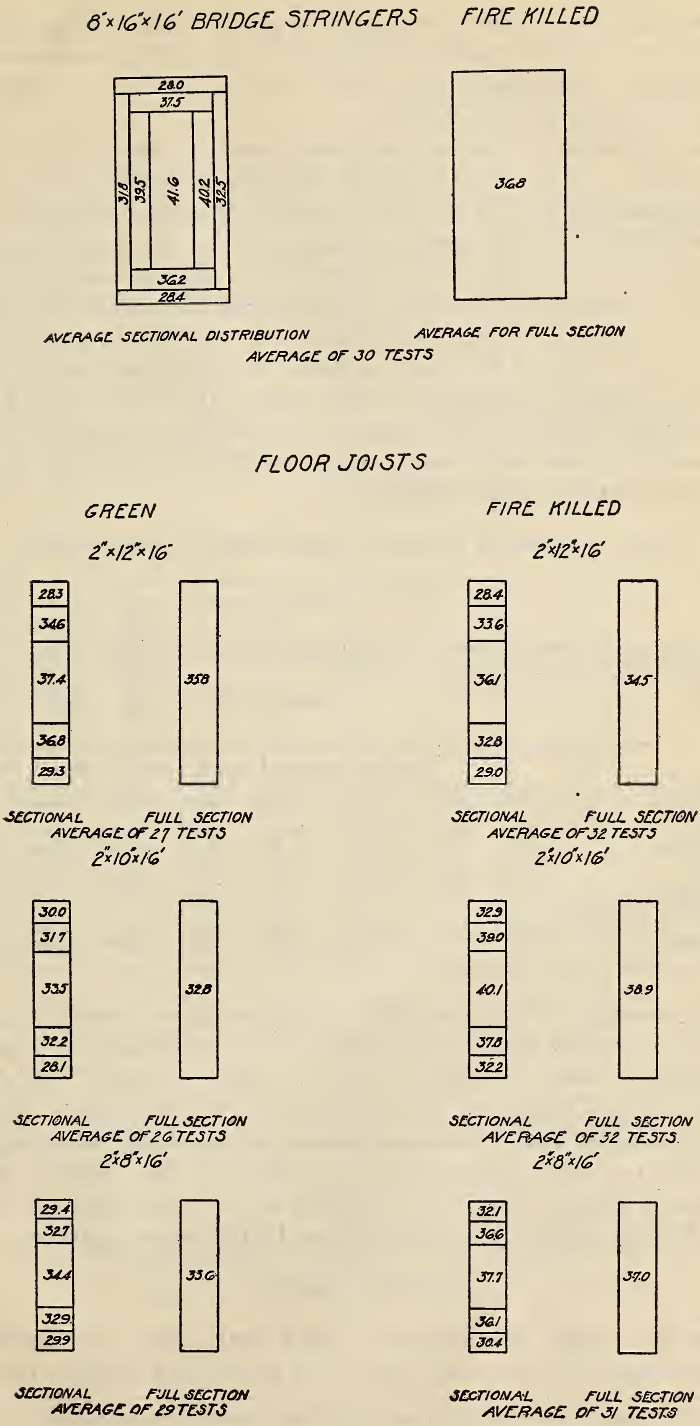

FIG. 2.—Moisture determinations on green and fire-killed Douglas fir.

Tests made some time previously on green bridge stringers of the same size at the University of Oregon, Eugene, Oreg., were used for comparison. These tests were made on material from growing trees, collected in Lane County, Oreg.

The comparative results from these tests are shown on figure 3 and Table 1. The green stringers were approximately 21 per cent stronger and 2 per cent less stiff than the fire-killed stringers. The greater strength of the green stringers can be attributed partly to their greater dry weight, which is on the average 2.1 pounds more per cubic foot than that of the fire-killed stringers, and partly to the method of testing. The green stringers were tested by applying the load at the center of the span, whereas the fire-killed stringers were tested by applying the load at third points, the latter being a more severe test.[1] Nevertheless, could the variables be eliminated, green stringers in these tests would undoubtedly show greater strength and approximately equal stiffness.

TABLE 1.—*Strength of green and fire-killed Douglas fir bridge stringers.*

Grade and condition.	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven-dry.			
Select:			*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*1,000 lbs.*
Green	59	11.9	31.2	38.9	29.6	4,346	6,753	1,654
Fire-killed	9	14.5	33.8	34.6	25.9	3,800	5,380	1,507
Merchantable:								
Green	79	10.7	31.5	36.8	28.0	3,895	5,878	1,481
Fire-killed	12	9.0	39.1	37.6	27.1	3,540	5,025	1,614
Common:								
Green	37	10.0	30.1	36.9	28.4	3,538	5,188	1,328
Fire-killed	9	9.8	36.8	35.8	26.2	3,150	4,570	1,444
All grades:								
Green	175	11.0	31.1	37.5	28.6	3,970	6,025	1,506
Fire-killed	30	10.9	36.8	36.2	26.5	3,500	4,990	1,531

The strength of the fire-killed bridge stringers varied with the grades into which they were divided. The modulus of rupture for the grades "select," "merchantable," and "common" is 5,380, 5,025, and 4,570 pounds per square inch, respectively. Thus the "merchantable" and "common" grade stringers are 93.4 per cent and 84.9 per cent, respectively, as strong as the "select" grade. This same general relation is apparent in the fiber stress at elastic limit, but the elasticity is little affected by difference in grade.

FLOOR JOISTS.

The floor joists, manufactured from both green and fire-killed timber selected in the same locality and tested by a uniform method,

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[1] Third-point loading is a more severe test because it subjects a greater portion of the beam to the maximum stress, and is therefore more likely to bring out any weakness caused by defects if such weakness exists.

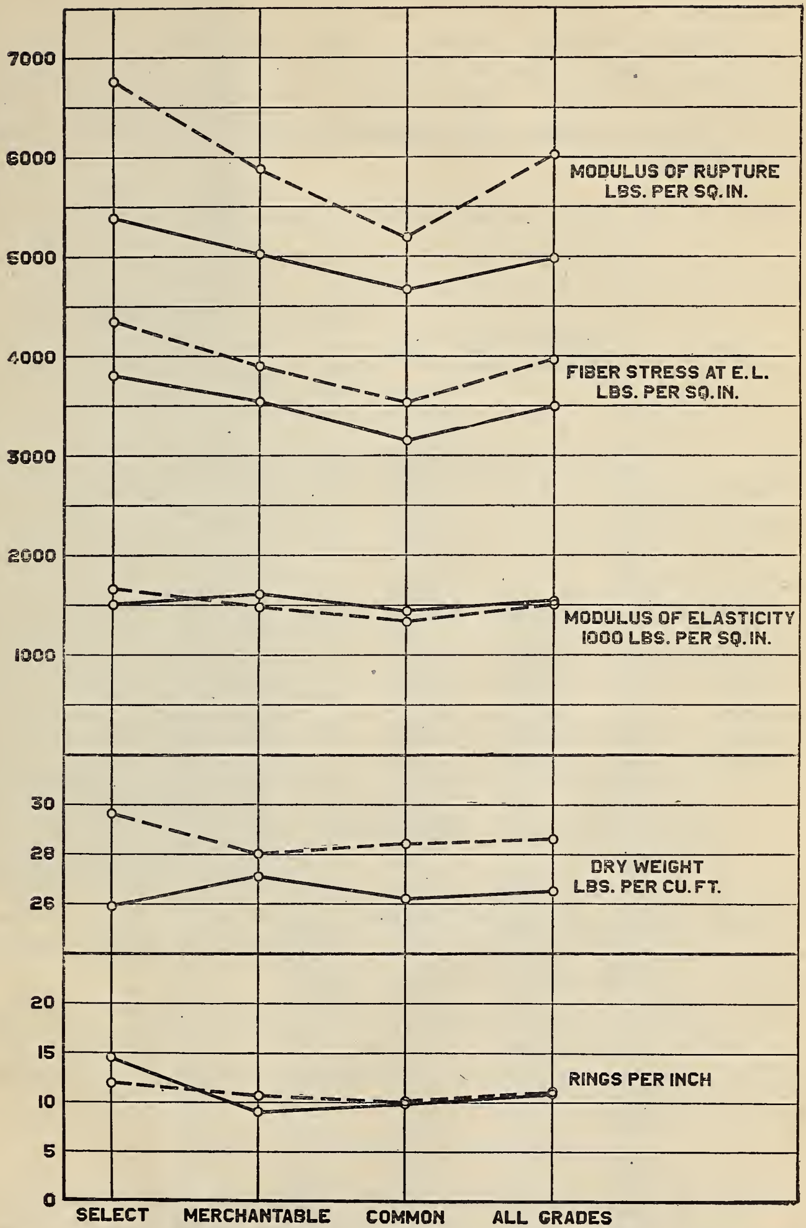


FIG. 3.—Comparison of results on green and fire-killed Douglas fir bridge stringers (....green; —— fire-killed).

form a better basis for a comparison of strength. They were tested on a span of 15 feet with a load applied at the third points of the span.

The result of the tests of joists of each size, divided according to the arbitrary grouping system, are given graphically in figure 4. This diagram also shows the effect of the location of defects on the strength of the joists. Table 2 gives the average strength of all sizes of joists by grades, and compares the green and fire-killed joists on that basis.

Table 2.—*Comparison of average results from green and fire-killed floor joists.*

[Sizes: 2″ by 12″ by 16′; 2″ by 10″ by 16′; and 2″ by 8″ by 16′.]

Grade.	Number of tests.	Rings per inch.	Summer wood.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
					As tested.	Oven-dry.			
Clear:			*Per ct.*	*Per ct.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*1,000 lbs.*
Green	15	33.5	[1] 50	30.0	35.0	27.0	3,937	6,044	1,684
Fire-killed	13	24.4	57	33.1	36.3	27.2	4,302	6,404	1,815
Ratio						100.7	109.3	105.9	107.8
Defects in volume I:									
Green	12	23.7	[2] 50	31.5	35.5	27.0	3,857	5,623	1,667
Fire-killed	16	17.2	[3] 55	38.7	37.7	27.3	4,027	5,966	1,812
Ratio						101.1	104.4	106.1	108.7
Defects in volume II:									
Green	24	16.4	[4] 47	35.3	35.9	26.5	3,630	5,485	1,668
Fire-killed	37	15.8	52	38.3	37.6	27.2	3,653	5,493	1,720
Ratio						102.6	100.7	100.2	103.2
Defects in volume II:									
Green	31	14.1	[5] 43	36.0	35.6	26.2	3,046	4,195	1,518
Fire-killed	29	15.6	49	[6] 35.2	34.6	[6] 25.6	2,927	4,025	1,470
Ratio						97.7	96.1	96.0	96.8
All grades:									
Green	82	19.8	[7] 46	34.1	35.6	[7] 26.5	3,498	5,120	1,614
Fir-killed	95	17.2	[8] 52	[8] 36.7	36.5	[8] 26.7	3,583	5,249	1,672
Ratio						100.7	102.5	102.6	103.6

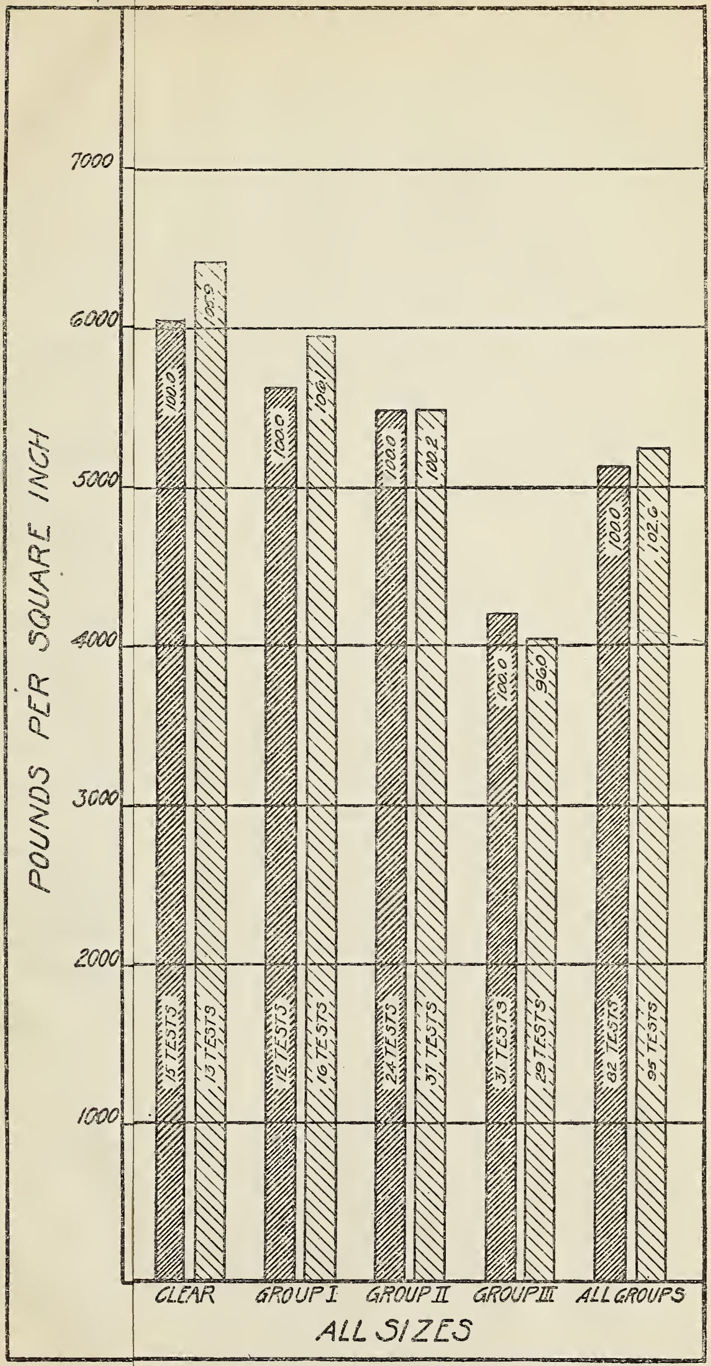
[1] Based on 11 tests.
[2] Based on 9 tests.
[3] Based on 15 tests.
[4] Based on 23 tests.
[5] Based on 30 tests.
[6] Based on 28 tests.
[7] Based on 73 tests.
[8] Based on 94 tests.

These tests, considering all sizes and groups, give the average strength value for fire-killed timber as equivalent to 102.6 per cent of the strength of live timber; the former shows a slightly greater strength in all but the most inferior grade.

Fire-killed joists of all groups combined have a stiffness of 103.6 per cent of that of green joists. Considering the groups separately, they maintain approximately equal stiffness in comparison with green joists.

COMPRESSION PARALLEL TO GRAIN.

After the tests on full-sized bridge stringers and floor joists had been made, the uninjured portions of the wood were sawed into test pieces for determining the following points: Strength in compression parallel to the grain, and in compression at right angles to the grain;


POUNDS PER SQUARE INCH
7000
6000
5000
4000
3000
2000
1000
100.0
105.9
100.0
106.1
100.0
100.2
100.0
96.0
100.0
102.6
15 TESTS
13 TESTS
12 TESTS
16 TESTS
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37 TESTS
31 TESTS
29 TESTS
82 TESTS
95 TESTS
CLEAR
GROUP I
GROUP II
GROUP III
ALL GROUPS
ALL SIZES

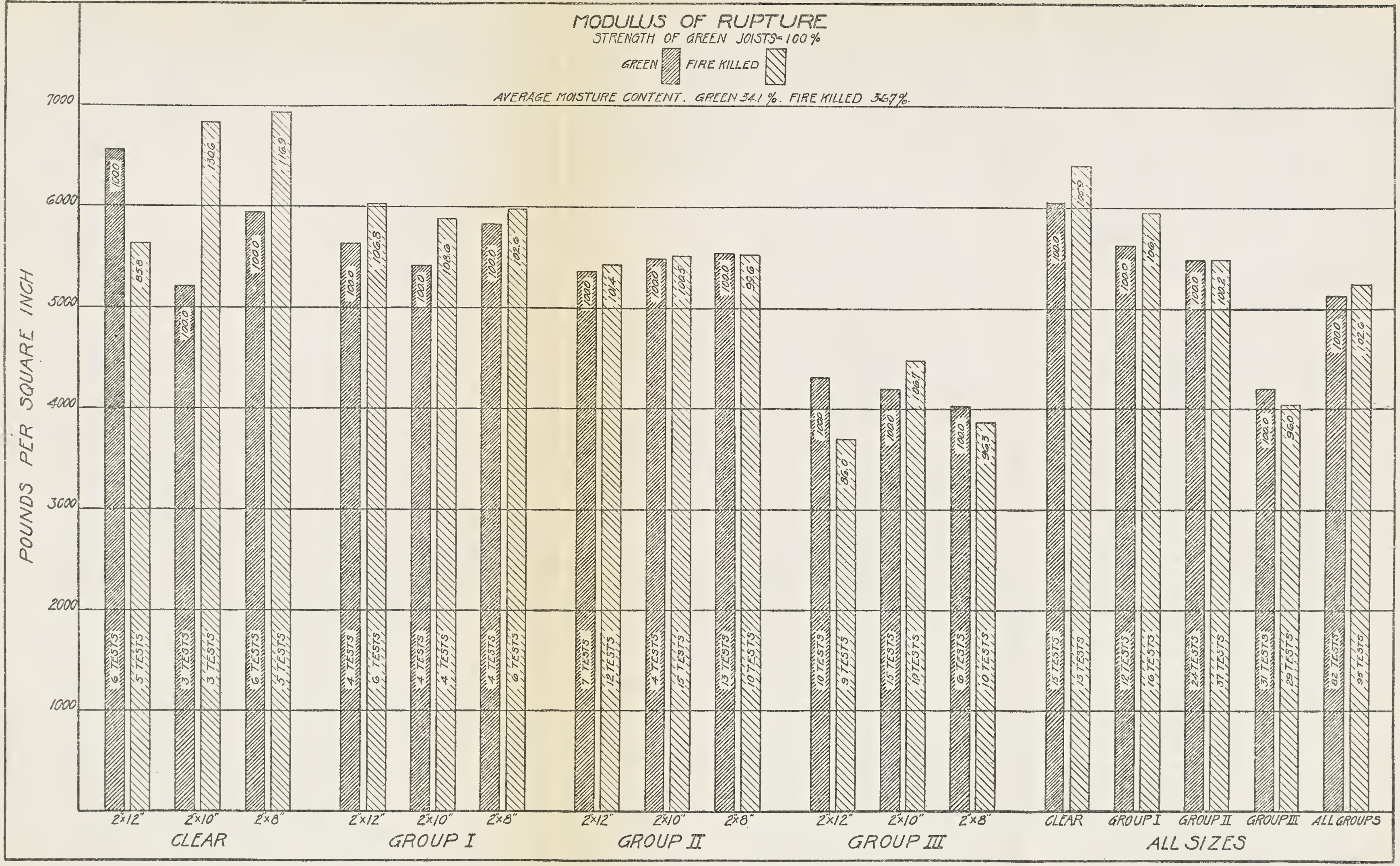

FIG. 4.– RESULTS OF TESTS ON GREEN AND FIRE-KILLED DOUGLAS FIR FLOOR JOISTS.

and, with small clear pieces, the bending strength and the shearing strength parallel to the grain.

TABLE 3.—*Strength of fire-killed Douglas fir in compression parallel to grain.*

[6″ by 6″ by 24″ specimens cut from bridge stringers.]

Grade.	Number of tests.	Rings per inch.	Summer wood.	Moisture.	Weight per cubic feet. As tested.	Weight per cubic feet. Oven-dry.	Compressive strength at elastic limit per square inch.	Crushing strength at maximum load per square inch.	Modulus of elasticity per square inch.
			Per ct.	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*1,000 lbs.*
Clear	35	Max. 32.0	60	59.4	48.1	31.2	3,960	4,420	3,425
		Avg. 16.5	49	35.0	36.0	26.6	[1] 2,963	3,662	[1] 2,158
		Min. 6.0	37	27.1	25.6	19.8	1,610	2,870	1,304
Knots 1″ and under in diameter.	39	Max. 20.0	54	76.2	50.4	29.8	3,630	4,230	3,030
		Avg. 10.0	43	[2] 35.3	35.7	[2] 26.0	[3] 2,678	3,250	[3] 1,682
		Min. 4.0	27	26.8	30.0	22.4	1,320	2,350	1,126
Knots over 1″ in diameter.	34	Max. 25.0	62	51.0	45.1	33.0	3,290	4,110	2,911
		Avg. 11.0	45	33.8	36.3	27.2	2,210	2,950	1,588
		Min. 4.0	27	27.5	29.8	19.7	1,310	2,190	1,012
Ratio, knotty to clear specimens:									
Knots 1″ and under in diameter.						97.7	90.4	88.8	77.9
Knots over 1″ in diameter.						102.2	74.6	80.5	73.6

[1] Based on 33 tests. [2] Based on 37 tests. [3] Based on 38 tests.

Table 3 shows the results of tests in compression parallel to the grain on 6″ by 6″ by 24″ specimens of fire-killed timber. The average strength at maximum load for all pieces is 3,290 pounds per square inch, while that for green Douglas fir, found by 515 tests on specimens of the same size, is 3,500 pounds per square inch.[1]

In these tests a study of the effect of knots was made. The specimens were divided into three classes, viz, clear pieces, pieces containing knots 1 inch and under in diameter, and those containing knots larger than 1 inch. The average maximum load for each of the three classes was 3,662, 3,250, and 2,950 pounds per square inch, respectively; that is, the second and third classes were, respectively, 88.8 per cent and 80.5 per cent as strong as the clear specimens.

TABLE 4.—*Strength of fire-killed Douglas fir in compression perpendicular to grain.*

[8″ by 16″ by 24″ clear specimens cut from bridge stringers.]

Number of tests.	Rings per inch.	Summerwood.	Moisture.	Weight per cubic foot. As tested.	Weight per cubic foot. Oven dry.	Compressive strenght at elastic limit per square inch.
		Per cent.	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
24	Max. 17.0	52	41.3	41.3	29.3	484
	Avg. 11.4	45	35.7	35.7	26.7	368
	Min. 5.7	37	28.2	32.2	24.3	291

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[1] Circular 189, Strength Values for Structural Timbers, by McGarvey Cline.

COMPRESSION PERPENDICULAR TO GRAIN.

The results of tests on 8″ by 16″ by 24″ specimens of fire-killed timber in compression perpendicular to the grain are given in Table 4. The pieces were free from defects influencing the strength of the wood. Their average compressive strength at elastic limit was 368 pounds per square inch.

BENDING AND COMPRESSION TESTS ON SMALL PIECES.

Bending tests were made on clear pieces of wood 2″ by 2″ in cross section and 30″ long. These pieces were tested on a span of 28″ by applying the load at the center of the span.

TABLE 5.—*Results of tests in bending on 2″ by 2″ by 30″ specimens cut from floor joists.*

Condition.	Number of tests.	Rings per inch.	Summerwood.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
					As tested.	Oven-dry.			
			Per ct.	*Per ct.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*1,000 lbs.*
Green	180	Max. 65.0	56	64.8	47.7	36.8	7,820	10,890	2,158
		Avg. 24.2	38	31.5	[1] 35.0	[1] 26.7	4,875	8,389	1,587
		Min. 5.0	26	26.0	30.1	23.1	3,130	5,510	1,073
Fire-killed	185	Max. 47.0	63	69.0	48.2	32.6	6,210	10,070	2,580
		Avg. 19.5	42	[2] 33.5	36.1	27.0	[2] 4,430	[2] 7,940	[2] 1,647
		Min. 4.5	30	27.5	26.4	20.2	2,460	5,020	1,120
Ratio, fire-killed to green						101.2	90.9	94.7	103.7

[1] Based on 179 tests.

[2] Based on 184 tests.

TABLE 6.—*Results of tests in compression parallel to grain on 2″ by 2″ by 8″ specimens cut from floor joists.*

Condition.	Number of tests.	Rings per inch.	Summerwood.	Moisture.	Weight per cubic foot.		Compressive strength at elastic limit per square inch.	Crushing strength at maximum load per square inch.	Modulus of elasticity per square inch.
					As tested.	Oven dry.			
			Per ct.	*Per ct.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*1,000 lbs.*
Green	179	Max. 66.0	51	49.2	44.9	33.3	3,470	5,230	3,118
		Avg. 29.0	[1] 39	32.0	35.8	27.1	[2] 2,705	3,714	[2] 1,944
		Min. 6.0	29	26.2	31.0	22.8	1,630	2,210	1,160
Fire-killed	127	Max. 47.0	60	69.7	49.8	34.3	3,500	4,400	2,333
		Avg. 22.8	[3] 43	37.2	38.2	27.8	[4] 2,543	3,480	[4] 1,776
		Min. 6.5	26	25.5	27.7	21.0	1,813	2,580	1,425
Ratio, fire-killed to green.						102.7	94.1	93.7	91.3

[1] Based on 177 tests.

[2] Based on 60 tests.

[3] Based on 123 tests.

[4] Based on 17 tests.

TABLE 7.—*Results of tests of fire-killed Douglas fir in shearing parallel to grain.*

[2″ by 3″ clear specimens cut from bridge stringers.]

Kind of shear.	Number of tests.	Rings per inch.	Summer-wood.	Moisture.	Weight per cubic foot.		Shearing strength at maximum load per square inch.
					As tested.	Oven dry.	
			Per cent.	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
Radial	35	Max. 29.0	57	57.7	48.7	30.9	839
		Avg. 12.1	[1] 42	36.8	35.8	26.1	650
		Min. 3.0	30	27.8	28.0	20.4	354
Tangential	16	Max. 28.3	62	56.8	48.9	33.8	819
		Avg. 14.9	50	36.1	36.9	27.0	626
		Min. 6.0	36	27.3	32.0	24.2	475
Diagonal	26	Max. 24.0	56	44.6	42.2	30.7	710
		Avg. 19.7	42	34.3	34.2	25.5	608
		Min. 4.0	31	29.1	29.8	22.0	435
All tests	77	Max. 29.0	62	57.7	48.9	33.8	839
		Avg. 12.2	[2] 44	35.8	35.5	26.1	631
		Min. 3.0	30	27.3	28.0	20.4	354

[1] Based on 34 tests.

[2] Based on 76 tests.

Figure 5 shows the result of tests of small pieces cut from the bridge stringers as compared with the results obtained in testing the full-sized stringers.

Tables 5 and 6 show the comparative strength of small beams and compression specimens, cut from green and fire-killed floor joists. The fire-killed beams were 94.7 per cent as strong as the green, based on the modulus of rupture. The maximum crushing strength of fire-killed wood was 93.7 per cent as great as that of the green wood.

SHEARING TESTS.

The results of shearing tests are given in Table 7. These tests were all made on specimens cut from fire-killed bridge stringers. The average radial, tangential, and diagonal shear was 650, 626, and 608 pounds per square inch, respectively. The average shearing strength of all pieces is 631 pounds per square inch.

CONCLUSIONS.

RATE OF DETERIORATION.

The rate of deterioration of fire-killed timber depends a great deal on the size of the timber and proportion of sapwood. Trees under 3 feet in diameter, if killed outright by a crown fire, are usually unmerchantable in 8 or 10 years; larger trees, with thin sapwood, may remain merchantable for 15 or 20 years.

STRENGTH.

The average results of tests of small specimens free from defects indicate that the wood of fire-killed Douglas fir, after a considerable number of years, is slightly weaker than that cut from green timber. The difference, however, is not great, and, in structural sizes containing the defects ordinarily found in timber, very largely disappears or is obscured by other factors, especially by the variability of the individual pieces in any lot of specimens. The bridge stringers of fire-killed wood were somewhat less strong than the green stringers with which they were compared; while the floor joists (of both kinds of wood) were about equal in strength. In stiffness, the fire-killed wood was fully equal to the green wood for all sizes tested.

In general, the tests indicate that the sound wood from fire-killed Douglas fir of the Pacific Northwest may safely be used for general construction purposes and that its merits are nearly if not quite equal to those of material from green, growing trees. It should be emphasized, however, that these results apply only to sound wood. Pieces showing indications of decay, whether cut from green or from dead trees, should be rigidly excluded where strength or durability is important.

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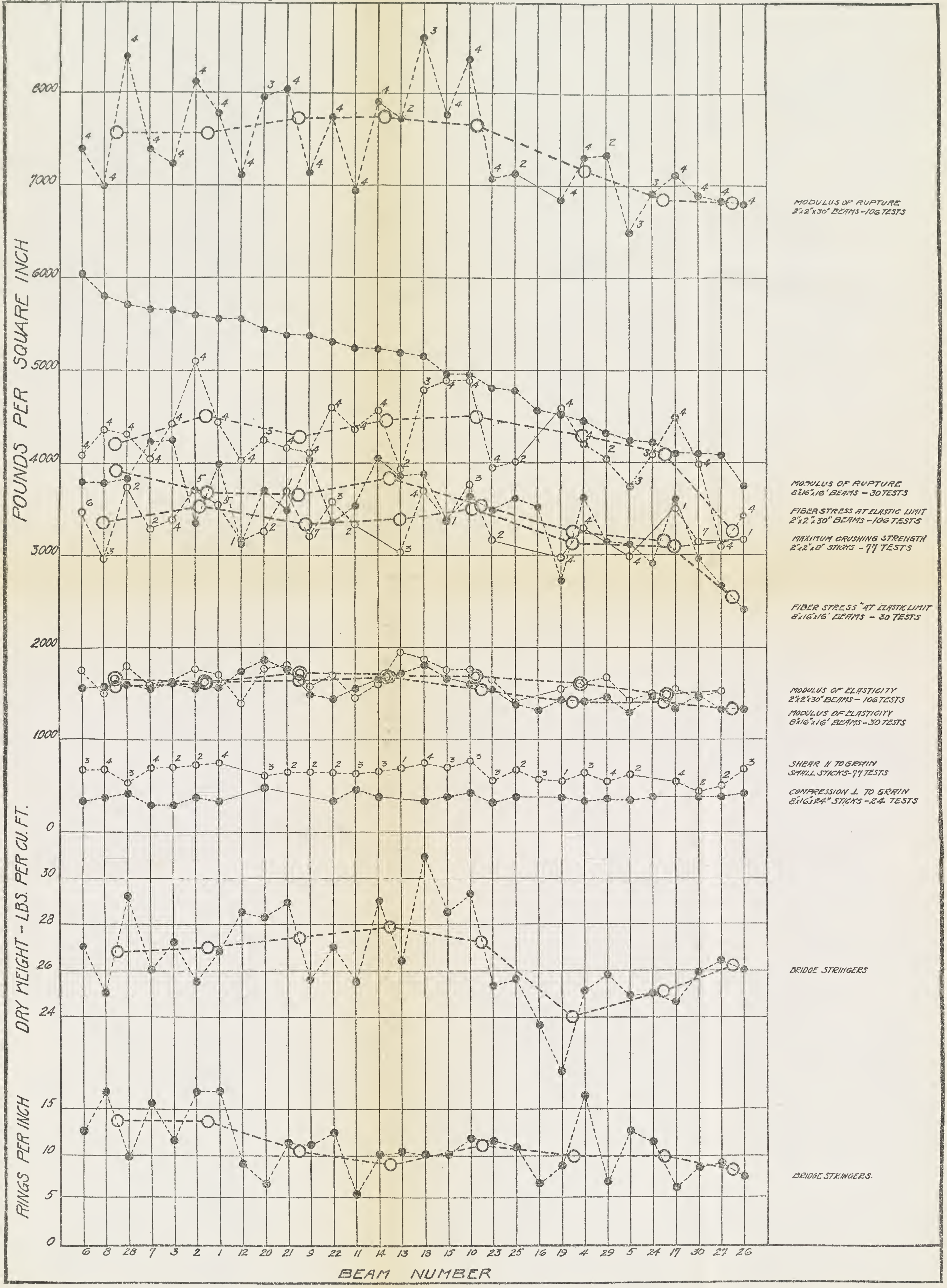

FIG. 5.—PROPERTIES OF FIRE-KILLED DOUGLAS FIR BRIDGE STRINGERS AND OF SMALL SPECIMENS CUT FROM THEM.